Frequency-Based Analysis of COP Trajectory for Quantifying Postural Control Mechanisms

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Summary

This study analyzes COP trajectory data from healthy males under four balance conditions to assess postural control. Mean dominant frequency is proposed to be employed for the assessment postural control, established through frequency analysis and feature importance scores.

Introduction

Sensory inputs from visual, vestibular and proprioceptive systems are crucial for balance control. Biomechanically, balance is maintained by adjusting the center of pressure (COP)[1]. COP trajectory is often used to assess postural disorders, but interpreting variables like displacement, velocity, etc. is challenging due to their inconsistency[2]. Thus, a more consistent and easily comparable COP-related feature is required. This study aims to establish a frequency feature for assessing postural stability.

Methods

COP trajectory in the anterior-posterior (A/P) and mediolateral (M/L) direction is collected from 15 healthy males under four conditions namely firm ground eyes open (FIRM EO) and closed (FIRM EC), and foam surface eyes open (FOAM EO) and closed (FOAM EC). It was collected for 60s at 200 Hz using two Kistler force plates and then preprocessed by removing the first and last 5s, then downsampling to 20 Hz. The signal was then decomposed into low (≤0.5 Hz), mid (0.5-5Hz), and high (≥5Hz) components[3]. FFT identified the dominant frequencies (frequency with highest amplitude) for each subject, and mean values (among the 15 subjects) are computed for each condition. Random forest regressor then assesses the influence of age, BMI, surface and vision factors on frequency features through feature importance scores.

Results and Discussion

Six frequency features are extracted from the COP trajectory under four experimental conditions as reported in Table 1. The mean dominant frequency increases from firm ground (eyes open and closed) to foam surface (eyes open and closed), as lowpass frequencies are linked to visual control [2], also shown in Figure 1. Figure 1 also establishes the effect of surface on the lowpass frequency parameters. Bandpass frequency have been reported to explain vestibular control[2], thus they are observed to not capture the stability trend in this case, as vestibular function is not studied. High frequency mean dominant frequencies are observed to be similar across conditions as reported in Table 1, as they relate to intrinsic muscle properties[2], which can be assumed to be consistent among the young, healthy subjects.

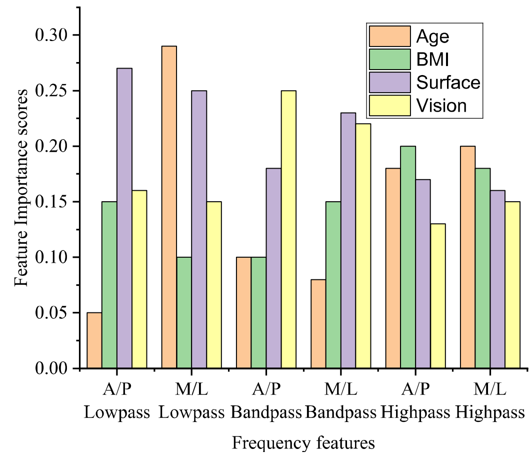

Figure 1. Feature importance scores of independent variables for different frequency features.

Conclusions

The analysis infers that low-frequency components of A/P and M/L COP trajectory can be employed to assess the effects of visual and somatosensory disorders on postural stability.

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References

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Table 1: Mean dominant frequency at different experimental conditions.

Experimental condition	A/P Lowpass	M/L Lowpass	A/P Bandpass	M/L Bandpass	A/P Highpass	M/L Highpass
FIRM EO	0.024	0.028	0.84	0.97	7.82	8.15
FIRM EC	0.038	0.024	0.73	1.13	8.10	8.14
FOAM EO	0.043	0.070	0.66	0.76	7.90	8.16
FOAM EC	0.044	0.126	0.70	0.60	7.50	8.19